The Effects of Magnetic Storm Phases on F-Layer Irregularities from Auroral to Equatorial Latitudes

Jules Aarons
Center for Space Physics
Boston University
Boston, MA 02215
phone: (617) 353-2639 fax: (617) 353-6463 e-mail: Aarons@buasta.bu.edu

Michael Mendillo
Center for Space Physics
Boston University
Boston, MA 02215
phone: (617) 353-2629 fax: (617) 353-6463 e-mail: Mendillo@buasta.bu.edu

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LONG-TERM GOAL

The aim of the research is to identify the necessary and sufficient conditions for the creation of ionospheric irregularities, primarily at equatorial latitudes. We are searching for means of identifying the parameters at high latitudes which produce effects at equatorial latitudes. The instability processes by which F layer irregularities develop are different for high latitude and for equatorial irregularities. At high latitudes, electric field changes during a storm, which can be highly localized, produce high intensity irregularities. At equatorial latitudes instability mechanisms, primarily the Rayleigh Taylor instability, has been thought to be the primary reason for the growth of plume like irregularities near the magnetic equator. Using radio and optical observations, we would like to find the triggering mechanism for equatorial irregularity development. Deep fades occur on the 250 MHz transmissions from FLEETSATCOM and AFSATCOM at equatorial, auroral, and polar latitudes. There is also phase and amplitude scintillation on the 1.2 and 1.6 GHz higher frequencies of the Global Positioning System's set of 24 satellites. In the IRIDIUM system at 1.6 GHz, the U.S. government has reserved several channels. Simply put, if we knew the forcing functions we could have the opportunity to forecast and predict when these irregularities interfere with communication and navigation systems.

OBJECTIVES

During a magnetic storm, the electric field increases at auroral latitudes. The turbulence resulting produces auroral and ionospheric irregularities. Slowly a shield is built up at high latitudes. At times the shield prevents activity at high latitudes from penetrating to equatorial latitudes. At other times, only a weak shield develops that prevents or enhances the lifting of the F layer at equatorial latitudes. This variable shielding is probably a function of time of day and the intensity of the magnetospheric source function, and hence the electric fields at the equator are also variable. We would like to contrast storms which affect equatorial irregularities and those that fail to affect these regions.

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APPROACH

We utilize GPS data collected at a number of stations at equatorial and high latitudes. We integrate data from multiple paths and data from multiple satellites at selected stations. The data emerges as Total Electron content (TEC) and rate of change of TEC (phase scintillation). For both high and equatorial latitudes, we are using data from the International GPS Service for Geodynamics (IGS). Thirty second values of phase differences between the 1.2 GHz and the 1.6 GHz signals of each GPS satellite were used. With the data set consisting of 30 second samples, thus limiting spectral characteristics, we have chosen to call the component of phase scintillation, phase fluctuations.

In addition optical recordings of the 6300 A emission of oxygen are made by local groups under the technical supervision of Boston University personnel. In the equatorial region the optical data depicts depletion regions in the equatorial ionosphere. We have compared these with radio measurements of many types.

WORK COMPLETED

Auroral Irregularity Development

1. High Latitudes:

At auroral and polar latitudes the unique data of GPS phase fluctuations taken simultaneously at many stations in the auroral oval were matched with the optical observations of the entire auroral oval of the Ultra-Violet Imager of the POLAR satellite. The development of both phase fluctuations from GPS and optical auroral development were correlated across the auroral oval. Two types of magnetic storms were identified as far as their effect on auroral irregularities. One has maximum impact as a function of storm time while the second type relies on local magnetic time to develop maximum intensity. We established that structured precipitation in the auroral region at E and F layer heights was taking place. The structured precipitation then leads to turbulence which in turn produces irregularities. The results have been accepted for publication by the Journal of Atmospheric and Solar-Terrestrial Physics.

2. Equatorial Region:

We have completed a summary of a month of ionospheric data from equatorial latitudes. These have now been put into the form for journal publication and the paper has been accepted by Space Science Reviews; it is the collaborative effort of a large group of primarily ONR contractors. It features multi-technique analysis of equatorial phenomena. These include days of minimal importance to scintillation studies and a worst case with what was serious disruption of observations. It is an attempt to look at morphology and occurrence levels rather than dramatic examples of plumes at the equatorial latitudes. The paper is a review of equatorial irregularities during a month at solar minimum and will be published in Space Science Reviews. The paper shows daily behavior rather than the worst case scenario. Additional data for validation of the concepts were taken during MISETA 97 when intensive observations were made in October and November 1997.

With the database of many stations in South America available to us, it is possible to look at the annual variation of phase fluctuations at sites on the magnetic equator. This has been done with phase fluctuation for the entire year of 1996, a period of low solar flux. We found that the occurrence of the phase scintillation that we observe is extremely well correlated with that of amplitude scintillations.

The patterns for Arequipa and Fortaleza in South America match those of published data on amplitude scintillation.

RESULTS

The connection between magnetic storm activity as shown by high latitude irregularity development and equatorial irregularity development as shown by pre-midnight equatorial plumes was shown for the first time by simultaneous measurements at high and equatorial longitudes; this took place during the October 1996 ABC Campaign with BU teaming with other ONR sponsored groups.

IMPACT/APPLICATION

Over the period of the Boston University studies with the Global Positioning System, a database has been built up. A new model of the effect of high latitude perturbation has been developed by B. Fejer at Utah State University. In this model auroral latitude magnetic data is used to determine the penetration of high latitude effects to equatorial electric fields. Initial work will be done to gather the database in a meaningful way with high latitude GPS recordings of phase scintillation and total electron content. We can then assess its use relative to forecasting strong equatorial scintillation, both amplitude and phase.

Data generated by groups involved in the MISETA program are now available on the WEB. The Boston University depletion data are presented along with observations of the brightness wave occurrence.

TRANSITIONS ACCOMPLISHED AND EXPECTED

Our next task is to determine from our database the characteristics of magnetic storms which have effects at the equator and storms that do not. We expect to develop additional data in this period of increasing solar flux to determine the changes that increasing solar flux and electron density do to the development of irregularities.

RELATED PROJECTS

In our study of the October 1996 data set we have integrated and will continue to work with the technical personnel of several groups. This is illustrated by the figure presented. Top left is a drawing of the radar returns at Jicamarca, Peru collected by the University of Illinois and Clemson University showing early morning irregularities. Top right is the Boston University depletion observations at Tucuman, Argentina, showing the same irregularity structure that the radar sees. The middle diagrams from Cornell University records the levels of amplitude scintillation and the bottom section is the Boston University analysis of data from GPS satellites of total electron content and the GPS phase fluctuations. In addition, the University of Massachusetts-Lowell ionosonde data were used.

NSF funding to many groups also studies equatorial plume development; their emphasis is on merging observations and first-principle numerical models. Our more empirical approach is to determine the necessary and sufficient conditions for the development of irregularities and the impact of the irregularities on trans-ionospheric systems from 250 MHz to 1.6 GHz.

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OCTOBER 4, 1996
Post Midnight Irregularities